8.1 INTRODUCTION

A safe water supply is essential to the production of healthy livestock and poultry. Water supplies contaminated with pollutants such as nitrates, pathogens, organic materials, and suspended solids can adversely affect livestock health and productivity. According to the U.S. Department of Agriculture's (USDA) Agricultural Research Service, livestock disease costs society over $17.5 billion dollars each year (U.S. Department of Agriculture, 2002).

Nitrate poisoning and pathogen-related illness are among the most common livestock diseases. In high concentrations, nitrate can be a health hazard to livestock. Nitrate poisoning is most common in ruminants (e.g., cows and sheep). Affected animals experience insufficient oxygen in the blood stream, which can lead to decreased growth and, in some cases, death.[1] A number of enteric (i.e., intestinal) pathogens may also be present in manure and can cause disease in livestock, including *Coccidiosis, Cryptosporidium, Giardia, E. coli, Salmonella, Campylobacter, and Listeria*.[2] Pathogen-related effects can include diarrhea, lowered milk production, decreased growth rates, and death (Xiao et al., 1993; Pell, 1994).[3]

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[1] State agricultural extension publications indicate that levels in excess of 100 mg/l nitrate-nitrogen may be harmful to cattle, particularly in combination with high nitrate feed (Hutchinson; Grant, 1993; Cassel, 1989).

[2] According to a University of Nebraska-Lincoln study, fecal coliform concentrations should be kept under 1 colony forming unit (CFU) per 100 ml of water to protect calves, and under 10 CFU per 100 ml to protect mature cattle. Similarly, fecal streptococcus should be kept under 3 CFU per 100 ml of water to protect calves, and under 30 CFU per 100 ml to protect mature cattle (Grant, 1993).

[3] Public and animal health agencies are also becoming increasingly concerned about the occurrence of *Salmonella typhimurium* (definitive type [DT] or phage type) 104, which is resistant to at least five antimicrobics: ampicillin, chloramphenicol, streptomycin, sulfonamides, and tetracycline.

The most common route of disease transmission is through fecal contact. For instance, large herds or flocks of animals are almost certain to produce known pathogens in their manure (Kuczynska and Shelton, 1999). AFOs that apply manure to on-site land may thus increase the incidence of disease by contaminating livestock watering sources.[4] Other CAFOs close to these source operations may also receive contaminated water and experience livestock illness and mortality.[5]

This chapter examines the impact of changes in manure management practices on animal health. Specifically, the analysis quantifies potential reductions in beef and dairy cattle nitrate poisoning and pathogen-related mortality resulting from the improved on-site manure application practices required by the revised CAFO rule.[6]

8.2 ANALYTIC APPROACH

To evaluate the impact of on-site manure application on animal health, EPA estimates beef and dairy cattle mortality attributable to nitrates and enteric pathogens present in groundwater livestock watering sources.[7] This analysis estimates the number of animals at risk from waterborne diseases and determines their baseline and anticipated change in mortality. EPA then monetizes the change in mortality by calculating the cost to replace the cattle. The sections below describe the approach in more detail.

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[4] The survival and transport of pathogens in groundwater is dependent on a number of factors related to the characteristics of the water and soil. Pathogens generally survive longer in waters where organic matter is readily available because the organic matter provides both substrate and nutrients for the organisms (Fallon and Perri, 1996). These conditions are generally present when manure is applied to agricultural lands.

[5] See Pumphrey and Haines, 2002 for a discussion of nitrate poisoning and pathogen-related disease exposure and incidences via groundwater contamination.

[6] In this analysis, EPA does not quantify impacts on other livestock sectors (e.g., swine). Based on a review of available literature on these sectors, EPA found limited on-site land application of manure and nominal projected benefits or insufficient data to estimate monetary benefits.

[7] For this analysis, EPA includes heifers and veal calves in the beef cattle sector.

8.2.1 Number of Cattle Affected

In this analysis, EPA examines the number of cattle at Large CAFOs that are covered under the effluent guideline and NPDES permit portions of the final rule.[8] EPA employs data on the number of animal units at these operations reported by the U.S. Department of Agriculture (Kellogg, 2002). EPA then multiplies these estimates by the number of cattle per animal unit (1.0 for beef cattle and 0.7 for dairy cattle) to estimate the average number of cattle at the large CAFOs. This approach generates estimates of over 11,873,000 beef cattle and over 2,352,000 dairy cattle at Large CAFOs.

Because not all CAFOs use groundwater for livestock watering and not all livestock watering sources are considered to be contaminated by pathogens or nitrates, EPA must scale the above number of cattle by estimates of the contamination risk. Exhibit 8-1 summarizes these scaling factors. Based on a USDA survey of water sources at farms with more than 1,000 cattle, 82.9 percent of livestock watering sources are wells, and approximately 13 percent of those wells exceed recommended nitrate levels of 100 ppm (U.S. Department of Agriculture, 2000). In addition, because other sources of nitrate can contaminate well water, EPA assumes that only 50 percent of nitrate contamination results from land application of manure.

In a 1984 report, EPA found that 19.8 percent of individual rural water supplies contained fecal coliform in excess of 1 colony forming unit (CFU) per 100 ml of water (Francis et al., 1984). Because these supplies often also serve as the source of water for livestock, the analysis uses this rate as a proxy for the rate at which water supplies for livestock are contaminated. For purposes of this analysis, EPA assumes that 100 percent of pathogen contamination results from land application of manure.

Exhibit 8-1

EXPOSURE SCALING FACTORS

	Nitrate	**Pathogens**
Percent of CAFOs using groundwater wells	82.9%[1]	82.9%[1]
Percent of wells contaminated	13.0%[2]	19.8%[3]
Percent attributable to manure management	50%	100%

Notes:
[1] Based on U.S. Department of Agriculture, 2000.
[2] EPA assumes wells with nitrate concentrations greater than 100 ppm to be contaminated.
[3] EPA assumes wells with greater than 1 CFU per 100 ml of water to be contaminated.

[8] The change in standards will also affect nitrogen and pathogen loads from Medium CAFOs, but an analysis of these impacts was not available when this report was submitted for publication.

Based on these scaling factors, EPA estimates that contaminated groundwater exposes almost 640,000 beef cattle and 127,000 dairy cattle to nitrate poisoning, and approximately 1,949,000 beef cattle and 386,000 dairy cattle to enteric pathogens. Based on a five-year herd replacement cycle, EPA estimates that 20 percent of the exposed cattle are calves.

8.2.2 Baseline Cattle Mortality

Exhibit 8-2 summarizes the nitrate poisoning and pathogen-related mortality rates for beef and dairy cattle. EPA applies these mortality rates to the number of exposed cattle to estimate the number of cattle expected to die absent the regulations. Exhibit 8-3 provides these baseline mortality estimates.

Exhibit 8-2

NITRATE POISONING AND PATHOGEN-RELATED MORTALITY RATES BY LIVESTOCK SECTOR

Health Impact	Sector	Mature Cattle	Calves
Nitrate Poisoning	Beef	0.00075	0.00036
	Dairy	0.00035	0.00015
Pathogens	Beef	0.00243	0.0078
	Dairy	0.00593	0.0321

Source: U.S. Department of Agriculture, 1997a.

Exhibit 8-3

BASELINE ESTIMATED CATTLE LOSSES PER YEAR AT LARGE CAFOs BY CONTAMINANT AND LIVESTOCK SECTOR

	Beef		Dairy	
Health Impact	**Mature Cattle**	**Calves**	**Mature Cattle**	**Calves**
Nitrate Poisoning	384	46	35	4
Pathogens	3,789	3,040	1,832	2,479
Total	4,173	3,086	1,867	2,483

Note: Totals may not sum due to rounding.

8.2.3 Predicated Change in Cattle Mortality

The benefits of improved animal health resulting from this rule are based solely on changes in on-site manure application practices and the resulting impact on the quality of on-site groundwater livestock watering sources. As such, this analysis employs two regulatory scenarios based upon anticipated nitrate and pathogen loading reductions that would result from:

- on-site manure application at a nitrogen-based limiting nutrient rate; and
- on-site manure application at a phosphorus-based limiting nutrient rate.

Using USDA GLEAMS model data, Exhibit 8-4 summarizes the expected change in edge-of-field subsurface nitrate and pathogen loadings.

To estimate the reduction in animal mortality that would result from this rule, EPA scales the baseline mortality estimates by the percentage change in nitrate and pathogen loadings. Due to the lack of appropriate dose-response curves, the analysis assumes that the relationship between reductions in pollutant loadings and associated mortality is linear. For example, an 87 percent reduction in edge-of-field subsurface pathogen loadings is assumed to result in an 87 percent reduction in pathogen-related mortality for the cattle currently at risk.

Exhibit 8-4

ESTIMATED CHANGES IN NITRATE AND PATHOGEN LOADINGS BY SECTOR AND LAND APPLICATION SCENARIO

Land Application Scenario	Sector	Nitrates	Pathogens (Fecal Coliform and Fecal Streptococcus)
Nitrogen-based	Beef	87.4%	57.5%
	Dairy	77.3%	69.3%
Phosphorus-based	Beef	90.6%	67.4%
	Dairy	82.7%	72.5%

Source: USDA GLEAMS model.

As shown in Exhibit 8-5, EPA estimates that nitrogen-based application rates would reduce annual beef and dairy cattle and calf mortality from nitrate poisoning and pathogens by 7,315 animals. Phosphorus-based application rates would reduce annual beef and dairy cattle and calf mortality from nitrate poisoning and pathogens by an estimated 8,154 animals.

Exhibit 8-5

ANNUAL REDUCTION IN CATTLE MORTALITY AT LARGE CAFOs BY LAND APPLICATION SCENARIO AND SECTOR

Land Application Scenario	Beef		Dairy		TOTAL	
	Mature Cattle	Calves	Mature Cattle	Calves	Mature Cattle	Calves
Nitrogen-based	2,512	1,787	1,296	1,720	3,808	3,507
Phosphorous-based	2,903	2,092	1,358	1,801	4,261	3,893

Note: Totals may not sum due to rounding.

8.2.4 Valuation

To determine the monetary benefit of reduced animal mortality that would result from changes in manure land application rates, EPA values the respective reductions in animal mortality based upon estimated animal replacement costs.[9] The available literature suggests that the replacement cost for the average beef or dairy cow is approximately $1,100 (1997 $), while the replacement cost for a day-old calf is approximately $50 (U.S. Department of Agriculture, 1997b). This analysis uses inflation-adjusted replacement cost values of approximately $1,185 and $54 for mature cattle and calves, respectively (2001 $).[10]

[9] Review of available literature reported by USDA revealed little information on the total cost of livestock mortality, such as pre-death animal healthcare costs and mortality management. The anticipated mortality reductions are also not expected to have market-level impacts. As a result, benefit estimates are limited to reduced animal replacement costs.

[10] EPA applies the Gross Domestic Product deflator to adjust the replacement cost values to 2001 dollars.

8.3 RESULTS

Exhibit 8-6 summarizes the results of the above analysis. Phosphorus-based application rates, which represent the proposed standard, would reduce annual cattle mortality from nitrate poisoning and pathogens at large CAFOs by 4,261 mature cattle and 3,893 calves. Using a replacement value of $1,185 for mature cattle and $54 for day-old calves, the annual monetary benefit would equal approximately $5.3 million. Similarly, the alternative nitrogen-based standard would reduce annual cattle mortalities at large CAFOs by 3,808 mature cattle and 3,507 calves. Based on the same replacement values, the annual monetary benefit of reduced beef and dairy cattle mortality under this standard would be approximately $4.7 million.

Exhibit 8-6

ANNUAL MONETARY BENEFIT OF REDUCED CATTLE MORTALITY AT LARGE CAFOs BY LAND APPLICATION SCENARIO AND SECTOR (2001 $, thousands)

Land Application Scenario	Beef	Dairy	TOTAL
Nitrogen-based	$3,073	$1,629	$4,702
Phosphorus-based	$3,553	$1,706	$5,259

Note: Totals may not sum due to rounding.

8.4 LIMITATIONS AND CAVEATS

EPA's analysis of reduced cattle mortality benefits from the revised CAFO regulations is subject to several significant uncertainties. These limitations include the following.

- This analysis does not examine potential reduced animal mortality at medium-sized CAFOs regulated under the effluent guideline and NPDES permit portions of this rule. Additionally, insufficient information exists to estimate potential reduced nitrate poisoning and pathogen-related mortality in other livestock sectors. Consequently, the analysis fails to consider potential benefits at these additional operations and sectors.

- This analysis examines the benefits of avoided mortality only and does not consider the benefits of avoided livestock and poultry morbidity from waterborne pathogens or excessive nitrate consumption. As a result, EPA considers neither slower animal growth rates nor the costs associated with disease prevention (e.g. antibiotics) or treatment.

- The lack of pathogen dose-response functions for cattle requires EPA to assume that percent reductions in pathogen loadings result in similar reductions in beef and dairy cattle mortality. This assumption may be inaccurate. For instance, it would predict the elimination of all mortality due to gastrointestinal illness at farms with contaminated groundwater contamination if all manure land applications were eliminated. The direction and magnitude of the bias related to this assumption, however, is unclear.

8.5 REFERENCES

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POTENTIAL BENEFITS OF REDUCED EUTROPHICATION OF U.S. ESTUARIES **CHAPTER 9**

9.1 INTRODUCTION

In its 1999 *National Estuarine Eutrophication Assessment*, the National Oceanic and Atmospheric Administration (NOAA) identified more than half of the 138 U.S. estuaries studied as either moderately or highly eutrophic. Eutrophication occurs when the addition of nitrogen, phosphorus, and other nutrients to a body of water stimulates the growth of algae. While this is a natural process, it is accelerated when human activity elevates loadings of nutrients above naturally occurring levels. Significant sources of excess nutrients include point source discharges (e.g., municipal wastewater treatment facilities), agricultural and urban runoff, and the deposition of atmospheric pollutants. CAFOs are a potential contributing factor.

Eutrophication degrades water quality in a variety of ways, including:

- reducing the amount of light that penetrates the water's surface, with subsequent loss of submerged aquatic vegetation;
- increasing the incidence of nuisance or toxic algae blooms; and
- increasing the quantity of decaying organic matter in the aquatic environment, which in turn draws down the concentration of oxygen dissolved in the water.

These water quality impacts result in loss of habitat, fish kills, and offensive odors, and thus adversely affect social welfare. According to NOAA:

> The implications are serious and affect not only the natural resources but also the economy and human health. The resource uses most frequently reported as being impaired were commercial fishing and shellfish harvesting. Recreational fishing, swimming, and boating, all of which contribute to tourism in coastal areas, were also reported as impaired to some degree. The reported risks to human health include the

consumption of tainted shellfish as well as direct skin contact or the inhalation/ingestion of water during an active bloom of toxic algae.

The revised CAFO regulations will reduce nutrient loadings to estuaries nationwide, thus reducing eutrophication and producing economic benefits. While the models and economic studies necessary to adequately measure these benefits are largely unavailable, this chapter presents, for nine selected estuaries, estimates of the impact of the final rule on nutrient loadings.[1] In addition, the chapter presents a case study of the economic benefits associated with reduced nutrient loadings to an estuary. The example focuses on improved recreational fishing opportunities in North Carolina's Albemarle and Pamlico Sounds. While the information presented is not comprehensive, it is indicative of the potential benefits of the final rule in reducing the eutrophication of U.S. estuaries.

9.2 ANALYSIS OF CHANGES IN NUTRIENT LOADINGS TO SELECTED ESTUARIES

9.2.1 Estuaries Analyzed

EPA's estimate of the impact of the final rule on nutrient loadings focuses on the following estuaries: Albermarle Sound; Cape Fear River; Delaware Inland Bays; Lower Laguna Madre; Matagorda Bay; New River; Pamlico Sound; Suwannee River; and Upper Laguna Madre. EPA selected these estuaries based on information in the NOAA report that identified each of them as adversely influenced by pollution from animal feeding operations.

9.2.2 Analytic Approach

EPA employs NWPCAM to characterize pollutant loadings to each estuary, both under baseline conditions and following implementation of the final rule (Bondelid, 2002).[2] The analysis involves three steps:

- *Step 1: Identify RF3Lite "terminal" reaches that end at coastlines* - Based on information provided in the RF3Lite data table, EPA identifies the reach of each stream network that is furthest downstream.

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[1] These benefits are not captured in Chapter 4's analysis of surface water quality benefits because (1) the National Water Pollution Control Assessment Model (NWPCAM) is primarily an inland river and stream model, and (2) the benefit transfer values based on the Carson and Mitchell (1993) willingness to pay (WTP) estimates only apply to changes in freshwater quality.

[2] For a more detailed discussion of NWPCAM, see Chapter 4.

- *Step 2: Overlay the RF3Lite terminal reaches from Step 1 onto NOAA's Coastal Assessment Framework (CAF)* - The CAF contains polygons in GIS format that identify each major estuarine system in the U.S. The estuaries identified for analysis by EPA are a subset of CAF's master list. CAF's coverage is at a less detailed scale than the RF3 GIS coverages, so the RF3Lite endpoints do not precisely align with the CAF polygons. The downstream endpoints of the terminal reaches identified in Step 1 are linked to the specific estuaries by "buffering" the CAF polygon boundaries, which in effect connects terminal reaches that are reasonably close to the CAF polygons. RF3Lite terminal reaches that are within the buffered boundary or fall within the polygon itself are then associated with the respective estuarine CAF polygon. This process generates a list of the RF3Lite terminal reaches that discharge into each of the estuaries analyzed.

- *Step 3: Produce pollutant loadings estimates for AFO/CAFO Baseline and Final Rule Scenarios* - Once the list of RF3Lite reaches associated with each estuary is developed, EPA relies on NWPCAM to estimate pollutant loadings to the estuaries from each terminal reach.

It is important to note that the analysis is limited to the impact of revised standards on Large CAFOs. The revised standards will also affect loadings of nutrients from Medium CAFOs, but the analysis of these impacts was not available when this report was submitted for publication.

9.2.3 Results

Exhibit 9-1 presents EPA's findings, including results of the analysis for both the phosphorus-based land application standard incorporated into the final rule and the nitrogen-based alternative standard, which EPA considered but did not select. As the exhibit shows, total loadings of phosphorus under the phosphorus-based standard are estimated to fall by 4.3 percent, while total loadings of nitrogen are estimated to fall by 0.4 percent. Under the nitrogen-based standard, the estimated reductions in phosphorus and nitrogen loadings are 2.1 percent and 0.1 percent, respectively. Under both standards, the estimated change in loadings varies from estuary to estuary, with the greatest reduction in loadings predicted for the Suwannee River estuary.

9.2.4 Limitations and Caveats

For the reasons discussed below, EPA's approach tends to under-estimate the total loadings of nutrients to estuaries and the reduction in loadings likely to result under the final rule.

- The analysis ignores loadings (and reductions in loadings) from non-RF3Lite terminal reaches that empty into the estuaries of interest.

Exhibit 9-1 EFFECT OF REVISED CAFO STANDARDS ON NUTRIENT LOADINGS TO SELECTED ESTUARIES[1]										
	Baseline Conditions		**Phosphorus-Based Standard**				**Nitrogen-Based Standard**			
			Nitrogen Load		**Phosphorus Load**		**Nitrogen Load**		**Phosphorus Load**	
Estuary	**Nitrogen Load (tons)**	**Phosphorus Load (tons)**	**Tons**	**Percent Change**	**Tons**	**Percent Change**	**Tons**	**Percent Change**	**Tons**	**Percent Change**
Albemarle Sound	4,684.31	330.66	4,668.20	-0.3%	317.71	-3.9%	4,680.13	-0.1%	325.94	-1.4%
Cape Fear River	1.48	0.13	1.48	0.0%	0.13	0.0%	1.48	0.0%	0.13	0.0%
Delaware Inland Bays	374.59	72.05	374.48	0.0%	69.59	-3.4%	374.68	0.0%	70.80	-1.7%
Lower Laguna Madre	597.81	82.41	597.11	-0.1%	79.01	-4.1%	597.22	-0.1%	80.03	-2.9%
Matagorda Bay	3,616.90	424.94	3,606.47	-0.3%	421.62	-0.8%	3,615.70	0.0%	423.89	-0.2%
New River	470.93	146.40	467.24	-0.8%	142.21	-2.9%	470.67	-0.1%	145.34	-0.7%
Pamlico Sound	2,636.61	250.05	2,619.79	-0.6%	240.06	-4.0%	2,633.03	-0.1%	246.32	-1.5%
Suwannee River	2,504.38	388.78	2,481.48	-0.9%	349.17	-10.2%	2,498.09	-0.3%	365.60	-6.0%
Upper Laguna Madre	1,654.10	174.52	1,653.08	-0.1%	170.82	-2.1%	1,653.26	-0.1%	171.94	-1.5%
Total	16,541.11	1,869.94	16,469.34	-0.4%	1,790.32	-4.3%	16,524.25	-0.1%	1,829.99	-2.1%

[1] The analysis accounts for changes in the regulations governing Large CAFOs only. The impact of revised standards for Medium CAFOs is not considered.

- Some portions of the estuaries of interest are part of the RF3Lite network. Because EPA's estimates of loadings to each estuary are based on loadings at the terminus of the RF3Lite network, they incorporate a degree of pollutant decay ("loss") that does not actually occur until after pollutants have entered the estuary.

- The analysis is likely to underestimate loadings associated with the atmospheric deposition of nutrients (especially nitrogen) from AFOs/CAFOs. While atmospheric deposition is an implicit component of NWPCAM's estimates of nonpoint source loadings, these estimates are based on observations from the 1980's, when atmospheric loadings from AFOs/CAFOs were likely much lower than they are today.

These caveats clearly affect EPA's estimates of total pollutant loadings, but their effect on EPA's estimate of the change in loadings following implementation of the final rule is less obvious. EPA's estimates of marginal changes in pollutant loadings are dependent upon the percentage of total loadings that are related to AFOs/CAFOs. As a hypothetical example, suppose that the baseline scenario reflects 100 pounds of total loadings, 30 pounds of which are from AFOs/CAFOs. If the reduction in AFO/CAFO loadings attributable to the final rule is 20 percent, the loadings change is 0.2 times 30, or 6 pounds. This 6 pounds represents an overall reduction in loadings of 6 percent, as opposed to the 20 percent reduction from AFOs/CAFOs. Therefore, systematic underestimation of the proportion of total loadings from AFOs/CAFOs – as is suggested by the third caveat above – will lead to an underestimate of the final rule's impact on total loadings.

In addition to the caveats listed above, we note again that the analysis is limited to the impact of the revised CAFO standards on loadings from Large CAFOs. Excluding effects on Medium CAFOs from the analysis further contributes to underestimation of the final rule’s impacts on total nutrient loadings.

9.3 CASE STUDY: ALBEMARLE AND PAMLICO SOUNDS

9.3.1 Introduction and Summary of Analytic Approach

To illustrate the potential economic benefits of the anticipated reduction in nutrient loadings to estuaries, EPA has evaluated the impact of the revised CAFO regulations on recreational fishing opportunities in North Carolina's Albemarle and Pamlico Sounds (Van Houtven and Sommer, 2002). The case study uses the approach described above to estimate annual nitrogen and phosphorus loadings (tons/year) from 17 “terminal” reaches to the Albemarle-Pamlico Sounds (APS) Estuary; the analysis relies on NWPCAM to characterize pollutant loadings both under baseline conditions and following implementation of the final rule. To evaluate the economic benefits associated with reduced nutrient loads to the APS Estuary, the case study employs a benefit transfer approach. This approach adapts value estimates from three previously conducted recreation-based studies, applying the adapted values to estimate recreational fishing benefits. Although the results of the analysis cannot be easily extrapolated to the rest of the country or to other benefit categories, they highlight the potential importance of improved water quality in U.S. estuaries.

The discussion that follows summarizes the studies employed in the benefit transfer analysis, highlighting key differences and similarities in their methods and findings. It then describes the selection of appropriate value estimates from these studies and the adaptation of these values to estimate the benefits of the CAFO rule.

9.3.2 Summary of Relevant Studies

The Albemarle-Pamlico case study relies on economic value estimates obtained from three studies conducted by researchers at North Carolina State University:

- Kaoru, Yoshiaki. 1995. "Measuring Marine Recreation Benefits of Water Quality Improvements by the Nested Random Utility Model." *Resource and Energy Economics* 17(2): 119-36.

- Kaoru, Y., V. Kerry Smith and Jin Long Liu. 1995. "Using Random Utility Models to Estimate the Recreational Value of Estuarine Resources." *Amer. J. Agric. Econ.* 77: 141-151.

- Smith, V. Kerry and Raymond B. Palmquist. 1988. "The Value of Recreational Fishing on the Albemarle and Pamlico Estuaries." U.S. Environmental Protection Agency. January.

These studies are based on common data sets. Specifically, they use recreation data obtained from a 1981-82 intercept survey of recreational fishermen that was conducted at 35 boat ramps or marinas within the APS Estuary (Kaoru, 1995; Kaoru, et al., 1995; Smith and Palmquist, 1988). The studies also employ common estimates of upstream point and nonpoint source nutrient loads to the APS Estuary. These data, which reflect conditions at approximately the same time the recreational activity survey was conducted, were acquired from NOAA's National Coastal Pollutant Discharge Inventory (NCPDI).

Exhibit 9-2 summarizes the key characteristics and findings of the three studies. As the exhibit indicates, the Smith and Palmquist study provides estimates of the benefits of a reduction in phosphorus loads; the studies by Kaoru and Kaoru et al. provide estimates of the benefits of reducing nitrogen loads to the APS Estuary. The studies are described in more detail below.

Exhibit 9-2

SUMMARY DESCRIPTION AND COMPARISON OF SELECTED VALUE ESTIMATES

	Smith and Palmquist (1988)			Kaoru, Smith and Liu (1995)						Kaoru (1995)	
	Value 1.1	**Value 1.2**	**Value 1.3**	**Value 2.1**	**Value 2.2**	**Value 2.3**	**Value 2.4**	**Value 2.5**	**Value 2.6**	**Value 3.1**	**Value 3.2**
Value Estimate											
mean value	$60.06	$20.61	$2.46	$6.52	$3.95	$3.38	$1.51	$1.27	$0.76	$4.70	$2.45
$ year	1981	1981	1981	1982	1982	1982	1982	1982	1982	1982	1982
per trip	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
per person	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water Pollutant											
nitrogen				✓	✓	✓	✓	✓	✓	✓	✓
phosphorus	✓	✓	✓								✓
change in loading	–25%	–25%	–25%	–36%	–36%	–36%	–36%	–36%	–36%	–25%	–25%
Value Concept											
WTP (compensating variation)				✓	✓	✓	✓	✓	✓	✓	✓
consumer surplus	✓	✓	✓								
Travel Cost Model											
random utility model (RUM)				✓	✓	✓	✓	✓	✓	✓	✓
nested site choice										✓	✓
varying parameter model	✓	✓	✓								
number of sites	11	11	8	35	35	23	23	11	11	35	35
Travel Cost Calculation											
per mile cost ($)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
percent of income/wage	100	100	100	100	33	100	33	100	33	100	100
avg speed (mph)	40	40	40	40	40	40	40	40	40	40	40
multi- and 1-day trips included	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Study Sample/Population											
sample size	1012	1012	1012	1012	1012	1012	1012	1012	1012	1012	1012
total number of observations	252	150	108	612	612	612	612	612	612	547	547
average number of trips/yr	29.7	29.7	33.3	29.7	29.7	29.7	29.7	33.3	33.3	32.04	32.04
mean household income	$32,174	$32,174	$31,759	$32,174	$32,174	$32,174	$32,174	$31,759	$31,759		

9.3.2.1 Smith and Palmquist (1988)

The primary objective of the Smith and Palmquist study was to investigate recreational fishing activity within the APS Estuary. The study employed two separate single-site travel cost models to estimate the demand for two major regional destinations ("composite sites"): the Pamlico Sound and Outer Banks areas. The Pamlico Sound region consisted of eight primary boat launching sites, while the Outer Banks region contained 11 sites.

Both regional demand estimates used the same explanatory variables, including reported catch rates. For the Pamlico Sound region, a single demand function was estimated, based on a sample of 108 survey respondents (i.e., n = 108) visiting one of the eight launch sites. The Outer Banks analysis estimated two separate demand functions. The first included the full sample of survey respondents visiting one of the 11 launch sites (n = 252). The second focused on a subset of this sample, defined as individuals residing within 200 miles of a site (n = 150).

Smith and Palmquist first estimated the demand and value of trips under the nutrient loading conditions that existed at the time of the survey. A separate regression model was used to estimate the relationship between phosphorus loadings and catch rates at the sites. Based on this relationship, the study predicted changes in catch rates and the resulting shift in trip demand due to changes in loadings. The changes in consumer surplus resulting from the estimated demand shifts were used to estimate the value of improved environmental conditions. The main improvement of interest with respect to the AFO/CAFO final rule is a 25 percent reduction in average phosphorus loadings to the APS Estuary. For the full sample and the sub-sample model, the Outer Banks analysis yielded benefit estimates of $60.06 and $20.61 (1981 dollars) per person-trip, respectively. The Pamlico Sound model estimated a value of $2.46 for the same reduction in phosphorus loads.

9.3.2.2 Kaoru et al. (1995)

Kaoru et al. used a random utility model (RUM) to investigate the demand for recreational fishing in the APS Estuary and estimate the value of improving water quality. Like the Smith and Palmquist study, Kaoru et al. used estimates of the impact of different pollutant loadings on catch rates to link water quality changes to total demand for recreational fishing trips. This linkage involved a two-step modeling procedure. First, a household production function (HPF) was estimated to predict expected catch rates for individuals based on variables such as equipment used, effort exerted, and the physical characteristics of the fishing site, including pollutant loadings. Kaoru et al. then used the HPF model to predict the impact of a 36 percent reduction in nitrogen loadings on expected catch rates. The changes in predicted catch rates were then incorporated into a site choice model using information from 612 boat fishing parties at 35 boat launching sites throughout the APS region. RUM models were estimated at three distinct levels of site aggregation. Aggregated site alternatives were created by grouping launch sites together based on location and other characteristics. This aggregation allowed the RUM to be estimated for a 35-site scenario, a 23-site scenario, and an 11-site scenario.

As Exhibit 9-2 shows, Kaoru et al. estimated separate values for each level of site aggregation (35, 23, 11) and for two specifications of the opportunity cost of time (OCT): the full wage rate and one-third the wage rate. This modeling approach produced six estimates of the economic benefit of a 36 percent reduction in nitrogen loadings. The estimated values range from $0.76 to$6.52 (1982 dollars) per person-trip.

9.3.2.3 Kaoru (1995)

The Kaoru study used a three-level nested RUM to estimate the value of water quality improvements in the APS Estuary. The 35 boat launching sites located in the APS Estuary were grouped into five subregions, based on location and other characteristics. The study investigated recreational fishing demand within these subregions using a nested model. The nested model approach breaks the recreational fishing decision into three stages: a decision on the duration of the trip (1, 2, 3, or more than 3 days), a decision on which of the five regions to visit, and a decision on which of the individual sites within the region to visit. The model estimation process was based on 547 observations from the fishing database. The study investigated the impact that different pollutant loadings and catch rates had on visitors' trip decisions, and the value that individuals placed on these differences. The impact of nitrogen and phosphorus loadings was specifically investigated in the second stage of the decision process (Regional Choice).

The regression analysis yielded coefficients with unanticipated signs for some parameters. For example, the analysis produced a positive coefficient for phosphorus loadings, suggesting that increases in phosphorus levels would increase the number of trips to a region. To address this unexpected outcome, the author reported values for pollutant reductions in two ways. First, the values associated with loading reductions that have the anticipated signs are reported, followed by the estimated values including both anticipated and unanticipated coefficient estimates. A 25 percent reduction in nitrogen loadings for the entire APS Estuary resulted in a benefit estimate of $4.70 (1982 dollars) per person- trip. When the positive coefficient estimates on phosphorus are included in the benefit measures, a 25 percent reduction in both nitrogen and phosphorus resulted in a benefit estimate of $2.45 per person-trip.

In contrast to the other two studies, the values cited above were estimated assuming no relationship between pollutant loadings and catch rates. When a 25 percent increase in catch rates was assumed to occur in conjunction with 25 percent loadings reductions, the benefit estimates increased slightly (to $4.88 and $2.63, respectively).

9.3.3 <u>Evaluation and Selection of Value Estimates</u>

As the summaries above indicate, the studies examined calculate the value of a reduction in pollutant loadings using similar estimation procedures; nevertheless, there are important differences in both methods and results. These differences warrant careful consideration in selecting the most appropriate values to be used in a benefit transfer procedure. Below we discuss these differences, many of which are also highlighted in Exhibit 9-2.

9.3.3.1 Reductions in Phosphorus Loadings

The study conducted by Smith and Palmquist estimated, per person-trip, the economic welfare gains associated with a 25 percent reduction in phosphorus loadings to the APS Estuary. The values listed in Exhibit 9-2 represent those generated from the Outer Banks full sample, the Outer Banks sub-sample (those residing within 200 miles of a site), and the Pamlico Region sample (Values 1.1, 1.2, and 1.3 respectively). These values span a wide range – from $60.06 per person-trip for the full Outer Banks model to $2.46 for the Pamlico model.

The second study that estimated values for reductions in phosphorus loadings is Kaoru (1995). Unfortunately, this study estimated the effects of (1) reducing both nitrogen and phosphorus loadings (Value 3.2) and (2) only reducing nitrogen loadings (Value 3.1); therefore, it is difficult to isolate the effect of changes in phosphorus loadings alone. More importantly, the regression analysis in this study produced unexpected (positive) signs on the coefficients for phosphorus loadings. This suggests that reductions in phosphorus loadings decreased recreational benefits, which is implausible. For this reason in particular, the Kaoru (1995) estimates for changes in phosphorus loadings are excluded from consideration for this benefit transfer.

9.3.3.2 Reductions in Nitrogen Loadings

Both Kaoru et al. (1995) and Kaoru (1995) used RUMs to estimate, per person-trip, the economic welfare gains associated with reductions in phosphorus loadings to the APS Estuary. Nonetheless, the studies differ significantly on the following points.

- **Magnitude of pollutant reduction –** Both studies estimate the benefits of a uniform percentage reduction in nitrogen loadings from all coastal counties adjacent to the APS Estuary. Kaoru et al. (1995) value a 36 percent reduction in loadings (through its effect on predicted catch rates and site choice), while Kaoru (1995) values a 25 percent reduction (through its effect on regional site choice).

- **Site definition –** The Kaoru et al. (1995) study presents six different values for a 36 percent reduction in nitrogen loadings – two for each of three models that vary with respect to the level of site aggregation. Based on a formal specification test, the authors conclude that their 35-site model is the most defensible; Exhibit 9-2 presents the results for this model as Values 2.1 and 2.2. The Kaoru (1995) study presents a single value for a 25 percent reduction in nitrogen loadings. This value is also based on a 35-site model. Exhibit 9-2 presents the results for this model as Value 3.1.

- **Calculation of travel costs** – As Exhibit 9-2 shows, travel costs are calculated in the same way for both studies, with one exception. Kaoru et al. (1995) specify two alternatives for the opportunity cost of time. One calculation uses the full wage rate, the other one-third of this rate. In contrast, the Kaoru study is based exclusively on an analysis that sets the opportunity cost of time equal to the full wage rate.

- **Number of observations** – Both studies rely on the same basic data set; however, the Kaoru et al. (1995) study employs a total of 612 observations, while the analysis presented in Kaoru (1995) is based on 547 observations.

9.3.3.3 Selection of Value Estimates

Based on the information above, the analysis retains the following values for the benefit transfer process:

- For reductions in phosphorus loadings, Value 1.1 and Value 1.3 from Smith and Palmquist (1988). Each value is for a distinct subregion of the APS Estuary, and both values are derived from models that were based on the full sample of intercept survey respondents. The distinctly higher benefit suggested by Value 1.1 ($60.06 per person-trip for the Outer Banks Site) raises some doubts about its validity, but not enough at this stage to exclude it from consideration.

- For reductions in nitrogen loadings, Value 2.1 and Value 2.2 from Kaoru et al. (1995), and Value 3.1 from Kaoru (1995). Each of these values is based on a 35-site model, which Kaoru et al. found superior to other specifications.

9.3.4 <u>Value Conversion for Benefit Transfer</u>

For benefit transfer purposes, it is necessary to express the values selected above on a consistent basis. This entails:

- applying the Consumer Price Index (CPI) to update all values to 2001 dollars; and

- deriving benefits values for unit changes in pollutant loads (i.e., a value for each one percent reduction in the quantity of nitrogen or phosphorus entering the estuary).

The latter adjustment is accomplished by dividing the value obtained from the literature by the percentage reduction in pollutant loads associated with that value. Thus, for example, a benefit of $2.50 per person-trip for a 25 percent reduction in nitrogen loads would equate to a benefit of $0.10 per person-trip for each percentage reduction.

A further adjustment is necessary to convert the values obtained from the literature to units that are compatible with NWPCAM's estimates of the changes in nutrient loads attributable to the final CAFO rule. NWPCAM estimates pollutant loads and changes in such loads in tons per year. According to Kaoru (1995), the average nitrogen load to the APS Estuary at the time the study was conducted was 1,741 tons per bordering county per year; for phosphorus, the average load was 260 tons per county per year. With 13 North Carolina counties bordering the APS Estuary, these values translate to a total of 22,633 tons of nitrogen and 3,380 tons of phosphorus loadings per year.

With these conversions, the values become:

- Value 1.1 – $0.147 per trip per Outer Banks fisher per ton reduction in phosphorus load per year;

- Value 1.3 – $0.0060 per trip per Pamlico fisher per ton reduction in phosphorus load per year;

- Value 2.1 – $0.0015 per trip per APS Estuary boat fisher per ton reduction in nitrogen load per year;

- Value 2.2 – $0.0009 per trip/per APS Estuary boat fisher/per ton reduction in nitrogen load per year; and

- Value 3.1 – $0.0015 per trip per APS Estuary boat fisher per ton reduction in nitrogen load per year.

9.3.5 <u>Benefit Transfer Calculation</u>

To estimate the total annual recreational fishing benefits of the final CAFO rule for the APS Estuary, it is necessary to combine the per-unit value estimates described above and the estimates of changes in pollutant loadings generated by NWPCAM with information on historic visitation rates to the APS Estuary. Specifically, total benefits can be calculated by the following formula:

$$TB_i = V_i \times \Delta L_i \times T$$

where

TB_i	=	the total annual recreational fishing benefits of reducing pollutant i under the final rule (dollars)
V_i	=	the annual per trip value per unit reduction of pollutant i (dollars per person-trip per ton per year)
ΔL_i	=	the change in loadings for pollutant i under the final rule (tons per year)
T	=	the total number of annual fishing trips to the APS Estuary (person-trips per year)

The calculation relies on 2001 visitation rates for recreational fishers in the APS Estuary, as provided by the Marine Fisheries Statistics Survey (MRFSS). This database contains information on the number, type and destination of recreational fishers for several coastal regions across the United States. The analysis disaggregated the MRFSS data from the regional and state level to include only trips to the APS Estuary, yielding an estimate of nearly 940,000 person-trips per year; boating fishers account for over seventy percent of these trips.

In calculating benefits, the analysis employed several additional assumptions regarding appropriate unit value estimates (V_i). Specifically:

- For nitrogen reductions, the unit value estimates obtained from the literature are based on a survey of boat fishers. The analysis assumes that these unit value estimates also apply to non-boat fishers.

- For phosphorus reductions, separate unit value estimates are available for Outer Banks and Pamlico Sound fishers (boat and non-boat fishers combined); however, MRFSS does not provide visitation rates for the Outer Banks. In addition, the Outer Banks analysis represents a very specific population and produces surprisingly high values. In light of these limitations, the analysis of the benefits of phosphorus reductions is based solely on the unit value estimate developed for Pamlico fishers (Value 1.3). This approach assumes that this value applies to all recreational fishers in the APS Estuary.

9.3.6 <u>Results</u>

Exhibit 9-3 reports the results of the benefit transfer calculations, presenting estimates of the total annual recreational fishing benefits for anticipated reductions in nitrogen and phosphorus loadings under both the phosphorus-based land application standard incorporated into the final

CAFO rule and the alternative nitrogen-based application standard, which EPA considered but did not select.[3] Based on the NWPCAM analysis, annual nitrogen loadings to the APS Estuary under the phosphorus-based standard are estimated to decrease 32.9 (short) tons per year, while annual phosphorus loadings are estimated to decrease 22.9 tons per year. The annual benefits attributable to the anticipated reduction in nitrogen loadings range from $28 thousand to $47 thousand, depending upon the unit value estimate employed. The benefits associated with the anticipated reduction in phosphorus loadings are estimated at approximately $129 thousand per year. In total, the annual recreational fishing benefits for the anticipated reductions in nitrogen and phosphorus loadings range from $158 thousand to $177 thousand.

Exhibit 9-3

ESTIMATED ANNUAL RECREATIONAL FISHING BENEFITS IN THE APS ESTUARY DUE TO NUTRIENT LOADING REDUCTIONS[1]
(2001 dollars)

Pollutant	Annual Trips	Baseline Loadings (tons/year)	Value of Reduction ($/ton/trip)	Phosphorus-Based Standard		Nitrogen-Based Standard	
				Loading Reduction (tons/year)	Economic Benefit ($/year)	Loading Reduction (tons/year)	Economic Benefit ($/year)
Nitrogen	939,020	7,320.9	0.0009 to 0.0015	32.9	$28,487 to $47,478	7.8	$6,715 to $11,192
Phosphorus	939,020	580.7	0.0060	22.9	$129,142	8.5	$47,594
Total Benefit				$157,629 to $176,621		$54,309 to $58,786	

[1] The analysis accounts for changes in the regulations governing Large CAFOs only. The impact of revised standards for Medium CAFOs is not considered.

Under the nitrogen-based standard, the estimated benefits are lower. Annual nitrogen loadings to the APS Estuary under this standard are estimated to decrease 7.8 tons per year, while annual phosphorus loadings are estimated to decrease 8.5 tons per year. The annual benefits attributable to the anticipated reduction in nitrogen loadings range from $7 thousand to $11 thousand, depending upon the unit value estimate employed. The benefits associated with the anticipated reduction in phosphorus loadings are estimated at approximately $48 thousand per year.

[3] As noted previously, the analysis of changes in nutrient loadings is limited to the impact of the revised standards on Large CAFOs. The revised standards will also affect loadings of nutrients from Medium CAFOs, but the analysis of these impacts was not available when this report was submitted for publication.

In total, the annual recreational fishing benefits for the anticipated reductions in nitrogen and phosphorus loadings range from $54 thousand to $59 thousand.

9.3.7 Limitations and Caveats

Although the annual benefit estimates presented in Exhibit 9-3 are not large, it is important to emphasize that these values only apply to recreational fishing in the APS Estuary. They do not capture benefits for other recreational and non-recreational uses of the estuary, nor do they capture potential non-use values.

In addition, the analysis described above is subject to uncertainties and has required a number of simplifying assumptions, each of which may lead to over- or under-estimation of benefits. In particular:

- The value estimates are based on fishing activity data that are over two decades old. The analysis assumes that the benefits of water quality changes have remained constant (in real terms) over this period.

- The original value estimates were based on pollutant loadings data from NOAA for the late 1970s and were estimated for rather large changes (25–36 percent reductions) in these loadings. The analysis assumes that similar percent reductions in the NOAA and NWPCAM estimates produce similar total loadings reduction estimates (in tons per year), and that per-trip benefits vary linearly with respect to loading reductions.

- The value estimates obtained from the literature were based on percentage reductions in nutrients that were uniform across the APS Estuary, whereas the reductions associated with the CAFO regulations are likely to be non-uniform. The analysis assumes that average per trip benefits do not vary with respect to the spatial distribution of the loadings reductions.

- The analysis assumes that unit value estimates for reductions in nitrogen loadings are the same for both boat and non-boat fishers, and that unit value estimates for reductions in phosphorus loadings are the same for fishers in Pamlico Sound and other parts of the APS Estuary.

Finally, the analysis is limited to the impact of the revised CAFO standards on loadings from Large CAFOs. Excluding effects on Medium CAFOs from the analysis is a source of downward (negative) bias in the estimated economic benefits of the final rule.

9.4 REFERENCES

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IMPROVEMENTS IN WATER QUALITY AND REDUCED DRINKING WATER TREATMENT COSTS — CHAPTER 10

10.1 INTRODUCTION

Total suspended solids (TSS) entering surface waters from AFOs can cause many problems for stream health and aquatic life. High sediment concentrations can also hinder effective drinking water treatment by interfering with coagulation, filtration, and disinfection processes. Treatment costs can rise as a result. Since more than 11,000 public drinking water systems throughout the United States rely on surface waters as a primary source, these costs can be substantial.

In this analysis, EPA utilizes the National Water Pollution Control Assessment Model (NWPCAM) to predict the impact of revisions to the CAFO standards on the ambient concentration of TSS in the source waters of public water supply systems. To measure the value of reductions in TSS concentrations, EPA estimates the extent to which lower TSS concentrations reduce the operation and maintenance (O&M) costs associated with the conventional treatment technique of gravity filtration. The following sections present the analytic approach, results of the analysis, and associated limitations and caveats.

10.2 ANALYTIC APPROACH

EPA's approach to this analysis comprises three steps:

- Identification of public drinking water systems and associated source waters that are potentially affected by discharges from AFOs/CAFOs;
- Linkage of source waters to TSS watershed concentrations projected by NWPCAM under baseline conditions and under the revised CAFO standards; and
- Estimation of reductions in drinking water treatment costs.

This three-step approach is explained in more detail below.

10.2.1 Identification of Public Drinking Water Systems

There are approximately 170,000 public water systems (relying on surface water and groundwater as a source) in the United States, as reported to EPA by the States for the fiscal year ending September 30, 2000 (U.S. EPA, 2000a). Of these systems, 11,403 are Community Water Systems (CWSs) that rely on surface water to serve 178.1 million people.[1] The water supplies of many of these CWSs may be adversely affected by discharges from AFOs/CAFOs. For this analysis, EPA employs two Agency databases to identify CWSs, the streams that serve as their water supplies, the populations they serve, and the operating status of each CWS: (1) the Water Supply Database (WSDB) (U.S. EPA, 2000b) and (2) the Safe Drinking Water Information System (SDWIS) (U.S. EPA, 2000a).

WSDB, also known as the Drinking Water Supply File, was developed by EPA in 1980 to identify the locations of public water utilities (i.e., CWSs), their intakes, and sources of water supplies (surface water or groundwater) across the United States. It contains information on approximately 7,500 public water utilities. Of these, 5,783 are dependent upon surface waters to serve the public and are linked to specific watersheds and geographic areas in EPA's Reach File.[2, 3] While no longer an EPA maintained database and limited in the number of water utilities

[1] CWSs supply water to the same population year-round.

[2] The Reach File is a series of national hydrologic databases that uniquely identify and interconnect the stream segments or "reaches" that comprise the nation's surface water drainage system. First created in 1982, four versions of the Reach File currently exist (RFI, RF2, RF3, and NHD), each with increasing resolution of digital hydrography data. Each stream segment is identified by a unique reach code. RF1 forms the geographic foundation for the Water Supply Database (WSDB); RF3 for NWPCAM.

[3] Watersheds are identified based on an 8-digit hydrologic unit code (cataloging unit), a national standard watershed identifier defined by the United States Geological Survey (USGS). The Reach File uses these codes as part of every reach number, which permits the NWPCAM results to be analyzed on a watershed basis.

it reports, WSDB is currently the only hydrologically linked database of drinking water utilities.[4] This link is essential to integrating the rest of the data with TSS stream concentrations projected by NWPCAM.

Since some of the information in WSDB is out-of-date, EPA obtains information on each water system's service population and operating status from SDWIS. SDWIS was first developed in 1997 and now serves as OW's major database for storing and tracking compliance and monitoring information on the nation's drinking water systems. The database was not designed to serve as a primary source of locational data and water utilities are not currently hydrologically linked to a geographic area or stream reach. Updating the locational information obtained from WSDB with available information from SDWIS ensures inclusion of the most current and readily available information in the analysis. For this analysis, production capacities for each water utility are estimated based on the population each water utility serves and a 1995 per capita water usage of 192 gallons per day (U.S. Bureau of the Census, 2001).[5]

10.2.2 Application of TSS Concentrations and Water System Data

EPA estimates reduced drinking water treatment costs based on projected reductions in TSS stream concentrations.[6] EPA links the site-specific water system data from WSDB and SDWIS with watershed-specific TSS concentrations projected by NWPCAM, under baseline conditions and under the revised CAFO standards. The analysis considers both the phosphorus-based manure application standard incorporated into the final rule and the alternative nitrogen-based standard, which the Agency considered but did not select. EPA calculates a median TSS concentration at the baseline and under the revised standards for each of the 2,003 watersheds (comprised of a total of 577,068 reach segments) covered by NWPCAM. The median concentrations are applied to each of the public water utilities located within the watershed. TSS watershed concentrations and complete water utility information (i.e., population served) are available for 5,509 of the 5,783 previously identified public water utilities that rely on surface waters to supply the public with water.

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[4] USGS and EPA have completed the development of the National Hydrography Dataset (NHD), a database that will provide a common framework for interrelating data contained in many EPA environmental water systems, including domestic water supplies. EPA is currently working on improving and verifying the geographic coordinates of drinking water intakes. Once this process is completed, identification of water systems and their water sources will be more comprehensive and readily available for modeling applications.

[5] This number includes commercial use of water.

[6] The analysis of changes in TSS concentrations is limited to the impact of the revised standards on Large CAFOs. The change in standards will also affect TSS loads from Medium CAFOs, but an analysis of these impacts was not available when this report was submitted for publication.

10.2.3 Estimation of Drinking Water Treatment Costs

EPA utilizes the Water Treatment Estimation Routine (WaTER), developed in a cooperative effort between the U.S. Department of the Interior, Bureau of Reclamation, and the National Institute of Standards and Technology, to estimate reduced drinking water treatment costs based on projected reductions in TSS stream concentrations (U.S. Bureau of Reclamation, 1999).

WaTER was developed by the Bureau of Reclamation to assist small communities in addressing their water quality problems and subsequently improving their drinking water quality. Using production capacity and raw water composition (e.g., TSS stream concentrations), WaTER calculates dose rates and cost estimates (construction and annual O&M) for 15 standard water treatment processes. Cost estimates are derived independently for each selected process. The program employs cost indices as established by the *Engineering News Record*, Bureau of Labor Statistics, and the Producer Price Index, and derives cost data from *Estimating Water Treatment Costs* (U.S. EPA, 1979) and *Estimating Costs for Treatment Plant Construction* (Qasim et al., 1992).

EPA assumes the conventional treatment technique of gravity filtration in estimating the reduced O&M costs for TSS removal. There are two components to gravity filtration: the backwashing system and the gravity filter structure. O&M costs are based on the area of the filter bed (applicable range 13-2600m^2) as determined by the system flow rate (production capacity) and TSS concentration. Default design values are as follows:

- wash cycle - 24 hours;
- TSS density - 35 grams per liter;
- media depth - 1 meter; and
- maximum media capacity - 110 L-TSS/m^3 (Degrémont, 1991).

Major O&M costs include materials, energy, and labor. The unit cost estimates and cost index values (March 2001) used for updating the 1979 EPA process costs are:

- Electricity Cost ($/kWhr) - 0.0796;
- ENR Labor Rate for Skilled Labor ($/hr) - 32.60; and
- ENR Materials Index - 2115.65.

These values were obtained from the *Engineering News Record* (ENR, 2001) and the U.S. Department of Energy (U.S. DOE, 2001). Off-site disposal costs and pretreatment costs, as well as construction costs, are not included in EPA's estimates. Cost saving estimates are based on the difference in O&M costs predicted between baseline conditions and conditions under the final rule.

10.3 RESULTS

Exhibit 10-1 summarizes the estimated annual benefits associated with improvements in surface water quality (i.e., TSS concentrations) and reduced drinking water treatment costs. The exhibit presents results for both the phosphorus-based manure application standard incorporated into the final rule and for the alternative nitrogen-based standard, which the Agency considered but did not select. The results are based on the analysis of 5,509 public drinking water systems located throughout the contiguous United States (i.e., 48 states and the District of Columbia are represented). The average production capacity for the water systems is 3.5 million gallons per day (MGD), with capacities ranging from 0.001 MGD to 614 MGD.[7]

Exhibit 10-1

ESTIMATED ANNUAL BENEFITS OF REDUCED DRINKING WATER TREATMENT COSTS[1,2]
(2001 $)

Regulatory Option	Average Production Capacity	Average TSS Reduction (mg/L)	Average Water System Benefit (per intake)	Total National Benefit (millions)
Phosphorus-Based Standard	3.5 MGD (0.001 to 614)	0.181	$111	$1.1 to $1.7
Nitrogen-Based Standard	3.5 MGD (0.001 to 614)	0.132	$69	$0.7 to $1.0

[1] The analysis accounts for changes in the regulation of Large CAFOs only. The impact of revised standards for Medium CAFOs is not considered.
[2] Based on analysis of 5,509 public drinking water systems extrapolated to 11,403 public CWSs on a national level.

TSS concentration data for the watersheds, as simulated by NWPCAM under baseline conditions and the revised CAFO standards, were provided by EPA in December, 2002 (U.S. EPA, 2002). Under the phosphorus-based standard, reductions in TSS stream concentrations averaged

[7] The average production capacity for the 11,403 CWSs is estimated to be 3 MGD, based on a total service population of 178.1 million (U.S. EPA, 2000a) and per capita water usage in 1995 of 192 gallons per day (U.S. Bureau of the Census, 2001).

0.181 mg/L, with reductions in TSS concentrations occurring in the water supply of 1,595 water systems. Of the remaining 3,914 water systems, 2,423 showed no change in TSS concentrations. The average benefit per water system for all 5,509 public drinking water systems was $111. Results were extrapolated to the national level based on the approximately 11,403 public CWSs nationwide that rely on surface waters as their primary source of water. Total national benefits for the phosphorus-based standard are estimated to range from $1.1 million to $1.7 million per year.[8] Under the nitrogen-based standard, reductions in TSS stream concentrations averaged 0.132 mg/L and occurred in the water supply of 1,401 water systems. Of the remaining 4,108 water systems, 2,472 showed no change in TSS concentrations. The average benefit per water system was $69. Estimated national benefits under this option range from $0.7 million to $1.0 million per year.

10.4 LIMITATIONS AND CAVEATS

The analysis of improvements in water quality, as it relates to reduced drinking water treatment costs, is subject to a number of uncertainties and assumptions that may lead to a potential under- or over-estimation of the benefits. Major limitations and assumptions are presented below:

- The analysis is based on a limited number of public water utilities (5,509). These public water utilities are assumed to be representative of public water utilities nationwide.

- The total population served by a public water utility was divided equally amongst the surface water intakes, where possible, for those utilities with multiple intakes.

- The default wash cycle of 24 hours is adjusted to between 8 to 96 hours (inclusive) (McGregor, 2001), when necessary, to maintain the area of the filter between the applicable range of 13-2600 m^2, as specified by WaTER. The wash cycle range is based on the economy of plant performance with wash cycles of less than 8 hours and on the risk of taste and odor problems with wash cycles greater than 96 hours. Benefits were assumed to be zero for those water utilities with wash cycles outside of the range (approximately 400 utilities).

- The cost estimates projected by WaTER are considered accurate within a +30% to -15% range and are based on average input values and default treatment design values. More accurate cost estimates can be determined given site-specific data.

[8] A range of benefits was estimated due to the uncertainties associated with the WaTER model.

- The analysis assumes only the conventional treatment technique of gravity filtration in estimating reduced O&M costs for TSS removal. Costs associated with pretreatment and sludge disposal are not included. The cost savings associated with these components of the water treatment process may exceed those estimated for the gravity filtration element.

In addition, the analysis is limited to the impact of the revised CAFO standards on pollutant loadings from Large CAFOs. Excluding effects on Medium CAFOs from the analysis is a source of downward (negative) bias in the estimated economic benefits of the final rule.

10.5 REFERENCES

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11.1 INTRODUCTION

This chapter summarizes EPA's estimates of the benefits associated with the revisions to the NPDES provisions and Effluent Limitation Guidelines (ELGs) pertaining to CAFOs. It first describes the Agency's approach to aggregating the results of the studies described in Chapters 4 through 10. It then describes EPA's approach to discounting future benefits and presents the aggregated benefits of the final rule, both in a single present value and as an annualized benefits stream. Finally, the chapter discusses the key limitations of the analysis and the implications of these limitations in characterizing the benefits of the revised CAFO standards.

11.2 INTEGRATION OF ANALYTIC RESULTS

To develop an integrated assessment of the benefits of the final rule, EPA simply adds the results of the analyses presented in Chapters 4 through 10. To the extent that these analyses address similar benefits, this approach may lead to double-counting and overestimation of benefits. In this case, however, EPA has determined that the potential for double-counting is small. Most of the analyses — the NWPCAM analysis of the benefits of improved surface water quality, the evaluation of potential improvements in commercial shell fishing opportunities, the assessment of potential reductions in the contamination of private wells, the evaluation of animal health benefits, the analysis of improved recreational opportunities in estuaries, and the assessment of savings in treatment costs for public water supply systems — examine different water resources and/or different uses of those resources. Thus, the benefits estimated in these analyses are clearly additive. The only possible source of double-counting lies in integrating the results of the NWPCAM analysis with EPA's evaluation of the benefits attributable to reducing the frequency and magnitude of fish kills.

The extent to which the NWPCAM analysis and the fish kills analysis may double-count benefits is unclear, but unlikely to be significant. Both analyses address changes in the quality of rivers, lakes, and streams.[1] In addition, at least some of the benefits of reducing the incidence of fish kills stem from the associated improvement in recreational fishing opportunities, a beneficial use which the NWPCAM analysis considers. Thus, some double-counting is possible. The NWPCAM analysis, however, is based upon modeling of surface water quality under steady state conditions; the analysis is not likely to capture all of the impacts of revised CAFO standards on circumstances (e.g., the overflow of a lagoon under severe storm conditions) that may lead to fish kills. This consideration suggests that at least some, if not all, of the benefits estimated in the fish kills analysis are incremental to those estimated in the NWPCAM analysis.

From a practical standpoint, the implications of any double-counting between the NWPCAM analysis and the fish kills analysis are minimal. At most, the estimated annual benefits of reducing the incidence of fish kills amount to a small percentage of the annual benefits estimated in the NWPCAM analysis. Thus, EPA has concluded that its approach to integrating the findings of the underlying analyses does not result in any significant degree of double-counting.

11.3 PRESENT VALUE OF BENEFITS

The results of the analyses in Chapters 4 through 10 are expressed as annual benefits streams. To calculate the present value of these benefits at the time new regulations are implemented, EPA employs three alternative real discount rates: three, five, and seven percent. The seven percent discount rate represents the real rate of return on private investments and is consistent with the rate mandated by the Office of Management Budget for analysis of proposed regulations. The three percent discount rate reflects the social rate of time preference for consumption of goods and services, and is consistent with the rate recommended by many economists for analysis of environmental benefits. The five percent discount rate represents the mid-point of the three to seven percent range.

In calculating the present value of benefits, EPA assumes an infinite time frame; i.e., as long as the regulations remain in effect the associated benefits will be enjoyed in perpetuity. As a practical matter, this approach is equivalent to assuming that the regulations will remain in effect for several generations, since the present value of benefits beyond this point approaches zero; however, it avoids the need to arbitrarily specify a period of time over which the regulations are assumed to remain in effect, and allows EPA to represent fully the present value of the benefits estimated. Appendix 11-A provides additional detail on the calculation of present values.

Exhibit 11-1 presents the results of the present value calculations for each of the benefit categories addressed in EPA's analysis, and for the final rule overall. The exhibit provides estimates for both the phosphorus- and nitrogen-based standards. As the exhibit shows, aggregate benefits under the phosphorus-based standard that the Agency selected range from approximately $2.2 billion

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[1] The data upon which the fish kills analysis is based include fish kill incidents below the head of tide. The NWPCAM analysis extends only to freshwater resources.

(assuming a discount rate of seven percent and employing the low-end of the underlying benefit estimates) to $11.8 billion (assuming a discount rate of three percent and employing the high-end of the underlying estimates). Under the nitrogen-based standard, which the Agency considered but did not select, aggregate benefits range from $2.0 billion to $8.0 billion. Within categories, the benefit estimates are lowest using the seven percent discount rate and highest using the three percent discount rate, reflecting the impact of alternative discounting assumptions on the present value of future benefits.

11.4 ANNUALIZED BENEFITS ESTIMATES

In addition to calculating the present value of estimated benefits, EPA has developed an estimate of the annualized benefits attributable to the final rule; these annualized values reflect the constant flow of benefits over time that would generate the associated present value. Appendix 11-B provides additional detail on the calculation of annualized benefits.

EPA assumes that benefits related to most water quality improvements will begin immediately after the revised regulations are implemented (i.e., because loadings will immediately decrease), and that these benefits will be constant from year-to-year. For these benefit categories, annualized benefits are equivalent to annual benefits, regardless of the discount rate employed. In the case of private well contamination, however, EPA assumes an uneven annual stream of benefits. As a result, EPA's estimates of the annualized benefits of reduced private well contamination depend upon the discount rate employed.

Exhibit 11-2 presents EPA's estimate of annualized benefits for each benefit category, and aggregates these estimates across benefit categories. The exhibit provides estimates for both the phosphorus- and nitrogen-based standards. As the exhibit shows, aggregate benefits under the phosphorus-based standard promulgated by EPA range from approximately $204 million per year to $355 million per year. Benefits under the alternate nitrogen-based standard, which EPA considered but did not select, range from approximately $141 million to $240 million annually. Again, note that variation in discount rates affects only the annualized benefits associated with reduced contamination of private wells; other annualized benefits remain constant regardless of the discount rate employed.

Exhibit 11-1

PRESENT VALUE OF THE ESTIMATED BENEFITS OF THE REVISED CAFO REGULATIONS UNDER ALTERNATE DISCOUNT RATES[1]
(2001 dollars, millions)

	Phosphorus-Based			Nitrogen-Based		
Benefits Category	**3%**	**5%**	**7%**	**3%**	**5%**	**7%**
Improved Surface Water Quality	$5,540 - $9,953	$3,324 - $5,972	$2,374 - $4,266	$3,413 - $6,087	$2,048 - $3,652	$1,463 - $2,609
Reduced Incidence of Fish Kills	$2 - $4	$1 - $2	$1 - $2	$1 - $2	$0.4 - $1	$0.3 - $1
Improved Commercial Shell Fishing	$10 - $113	$6 - $68	$4 - $49	$3 - $67	$2 - $40	$1 - $29
Reduced Contamination of Private Wells	$1,523	$741	$441	$1,643	$800	$476
Reduced Contamination of Animal Water Supplies	$175	$105	$75	$157	$94	$67
Reduced Eutrophication of Estuaries Albemarle-Pamlico Case Study	not monetized $5 - $6	not monetized $3 - $4	not monetized $2 - $3	not monetized $2	not monetized $1	not monetized $1
Reduced Water Treatment Costs	$37 - $57	$22 - $34	$16 - $24	$23 - $33	$14 - $20	$10 - $14
All Categories[2]	$7,291 + [B] - $11,831 +[B]	$4,202 +[B] - $6,926 + [B]	$2,194 +[B] - $4,859 + [B]	$5,242 +[B] - $7,990 + [B]	$2,959 + [B] - $4,608 + [B]	$2,019 + [B] - $3,197 + [B]

[1] The analysis accounts for benefits associated with the revised regulations for Large CAFOs only. The impact of revised standards on Medium CAFOs is not included.
[2] Discrepancies between these totals and the sum of the figures in each column are due to rounding.
[B] Represents non-monetized benefits.

Exhibit 11-2

ESTIMATED ANNUALIZED BENEFITS OF THE REVISED CAFO REGULATIONS UNDER ALTERNATE DISCOUNT RATES[1]
(2001 dollars, millions)

	Phosphorus-Based			Nitrogen-Based		
Benefits Category	**3%**	**5%**	**7%**	**3%**	**5%**	**7%**
Improved Surface Water Quality	$166.2 - $298.6	$166.2 - $298.6	$166.2 - $298.6	$102.4 - $182.6	$102.4 - $182.6	$102.4 - $182.6
Reduced Incidence of Fish Kills	$0.1	$0.1	$0.1	$0.0 - $0.1	$0.0 - $0.1	$0.0 - $0.1
Improved Commercial Shell Fishing	$0.3 - $3.4	$0.3 - $3.4	$0.3 - $3.4	$0.1 - $2.0	$0.1 - $2.0	$0.1 - $2.0
Reduced Contamination of Private Wells	$45.7	$37.1	$30.9	$49.3	$40.0	$33.3
Reduced Contamination of Animal Water Supplies	$5.3	$5.3	$5.3	$4.7	$4.7	$4.7
Reduced Eutrophication of Estuaries Albemarle-Pamlico Case Study	not monetized $0.2	not monetized $0.2	not monetized $0.2	not monetized $0.1	not monetized $0.1	not monetized $0.1
Reduced Water Treatment Costs	$1.1 - $1.7	$1.1 - $1.7	$1.1 - $1.7	$0.7 - $1.0	$0.7 - $1.0	$0.7 - $1.0
All Categories[2]	$218.9 + [B] - $355.0 + [B]	$210.3 + [B] - $346.4 + [B]	$204.1 + [B] - $340.2 +[B]	$157.3 + [B] - $239.8 + [B]	$148.0 + [B] - $230.5 + [B]	$141.3 + [B] - $223.8 + [B]

[1] The analysis accounts for benefits associated with the revised regulations for Large CAFOs only. The impact of revised standards on Medium CAFOs is not included.
[2] Discrepancies between these totals and the sum of the figures in each column are due to rounding. Values are rounded to the nearest $100 thousand.
[B] Represents non-monetized benefits of the rule.

11.5 LIMITATIONS OF THE ANALYSIS AND IMPLICATIONS FOR CHARACTERIZING BENEFITS

The results presented above are based on the analyses presented in Chapters 4 through 10, and are subject to the specific uncertainties and limitations that are discussed in detail in each of these chapters. Beyond these limitations, however, it is important to note that EPA's analysis does not attempt to comprehensively identify and value all potential environmental changes associated with proposed revisions to the CAFO regulations. Instead, the Agency focuses on specific identifiable and measurable benefits. The impacts of the regulatory proposal likely include additional benefits not addressed in these analyses, such as improved recreational opportunities in near-coastal waters beyond those analyzed in Chapter 9; improvements in commercial fishing; improvements in near-stream activities; and non-water related benefits, such as potential reductions in odor from waste management areas. In light of these limitations, EPA believes that the benefits quantified in this report represent a conservative estimate of the total benefits of the revised CAFO standards.

Appendix 11-A

CALCULATION OF PRESENT VALUES

The present value (*PV*) of a benefit (*B*) to be received *t* years from now is determined by the following equation:

$$PV = B_t / (1 + r)^t$$

where *r* represents the annual discount rate. Thus, the present value of an annual stream of benefits from Year 1 through Year *n* is calculated as follows:

$$PV = \sum_{t=1}^{n} B_t / (1 + r)^t$$

When B_t is constant – i.e., when benefits (*B)* each year are the same – and *n* approaches infinity, the equation above can be simplified to:

$$PV = B / r$$

EPA employs the above equation to calculate present values for all categories of benefits that are assumed to remain constant from Year 1 onward; i.e., for all categories except reduced contamination of private wells. In the latter case, benefits are assumed to increase in a linear fashion until Year 27, and then to remain constant. Thus, the value in Year 27 (V_{27}) of the constant, infinite stream of benefits (*B*) expected to accrue from that year forward is calculated as:

$$V_{27} = B / r$$

In calculating the present value of reduced contamination of private wells, EPA sets the value of B_{27} equal to that of V_{27}. The present value of benefits is then determined using the following equation:

$$PV = \sum_{t=1}^{27} B_t / (1 + r)^t$$

Appendix 11-B

CALCULATION OF ANNUALIZED BENEFITS

The constant annual benefit A that, over a period of n years, equals the estimated present value (PV) of benefits is determined by the following equation:

$$A = \mathrm{PV}(r) / (1-[1 / (1 + r)^n])$$

where r represents the annual discount rate. As n approaches infinity, this equation simplifies to:

$$A = PV(r)$$

EPA uses the equation above to calculate the annualized benefits reported in this analysis.